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Review Paper on Millet: Production, Nutrients, Processing, and Food Products for Health and Sustainability

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***Abstract*— *Millet is an important ancient cereal crop known for its nutritional value. It has served as a staple food for various cultures for thousands of years, offering a rich source of carbohydrates, protein, fiber, vitamins, and minerals. Millet grains are small, round, and have a hard outer layer, making them versatile for processing into various food products. They are commonly ground into flour or grits for making porridge, bread, and crackers, and can also be used in fermented foods like beer and sourdough. In the context of climate change, water scarcity, and global population growth, millet's role in ensuring food security is becoming increasingly important. Food scientists, technologists, and nutritionists are showing growing interest in millet due to its nutritional benefits and potential health advantages. This review paper aims to enhance the processing methods of millet to support its consumption by a large and expanding population.*

***Keywords*— Functional characteristics, millet, nutritional value, processing.**

I. INTRODUCTION

An ancient crop that was cultivated early on is millets, a type of grain belonging to the Poaceae grass family. They are small-seeds and in round shape that are poised to become a global sensation. Millets, have been renamed as "nutricereals" to highlight their nutritional value and importance. Millets are highly nutritious food that offer a potential solution to the increasing prevalence of gut-related diseases and metabolic disorders. These grains, often termed "superfoods," are recognized for their exceptional nutrient density and health benefits. Despite once being a staple in traditional Indian cuisine, millets have largely been replaced by rice and wheat in modern diet. They are rich in protective polyphenols like hydroxycinnamic acid, catechin, quercetin, luteolin, orientin, apigenin, and isoorientin. These polyphenols exhibit antioxidant properties by scavenging free radicals and possess anti-inflammatory effects. Finger millet stands out for its high flavonoid content, whereas foxtail millet, pearl millet, and proso millet are notable for their elevated levels of phenolic acids. Ferulic acid, a type of hydroxycinnamic acid, is particularly abundant in millets and is known for its potent antioxidant capabilities (Jena *et al.*, 2023).

Millets are easy to cultivate due to their climate resilience and drought-tolerant properties, enabling them to survive in extreme temperatures. They can be cultivated in both kharif and rabi seasons and have a good shelf life. It require significantly less water for irrigation compared to wheat and rice, which require 26 times more water. They use 70% less water than rice and grow 50% faster than wheat. Millets are naturally resistant to pests, which reduces the necessity for pesticides. Millets exhibit adaptability to a wide range of ecological conditions, minimal vulnerability to environmental stresses, low irrigation requirements, and optimal growth and productivity under minimal input conditions (Kole et al., 2015). Despite being overlooked previously, the importance of millets is gaining recognition

in today's world (Goron and Raizada, 2015). The biodiversity of millets provides researchers with access to potential candidate genes for further improving crop traits. Therefore, millets, particularly improved varieties of small millets, hold great promise in addressing the challenges posed by climate uncertainties and constraints on natural resources (Den Herder et al., 2010; Dai, 2011).

International Year of Millets 2023: Initiatives and Proposed Activities:

The Indian government proposed to the United Nations for declaring the year 2023 as the International Year of Millets (IYOM). With the support of 72 other countries, the United Nations General Assembly (UNGA) officially declared 2023 as the International Year of Millets on March 5, 2021. The initiative of the Indian government for celebrating IYOM 2023 involves increasing awareness of the nutritional benefits of millets and enhancing the acceptability of value-added millet products across the country and around the world. The International Year of Millets offers a significant opportunity to:

- Enhance the contribution of millets to food security.
- Increase global millet production.
- Improve efficiency in processing, transport, storage, and consumption of millets.
- Promote sustainable production practices and ensure millet quality with the involvement of stakeholders (APEDA, 2023).

HISTORY AND ORIGIN

The history and origin of millets trace back to ancient times, with evidence suggesting that millets were among the earliest cultivated crops in human history (Gupta & Das, 2005). Millets are believed to have originated in Africa and Asia, where they were domesticated around 10,000 years ago, making them one of the earliest crops to be cultivated by humans (Harlan, 1992). Archaeological findings from sites in China and India provide insights into the early cultivation and use of millets by ancient civilizations (Kumar & Ganesamurthy, 2015). Millets played a crucial role in sustaining ancient populations due to their resilience in diverse agro-climatic conditions and their nutritional value (Harlan, 1992). They were staples in the diets of early civilizations like the Harappan civilization and ancient Chinese dynasties (Gupta & Das, 2005). Over time, millets spread to other parts of Asia, Europe, and Africa, adapting to different cultural and environmental contexts (Kumar & Ganesamurthy, 2015).

TYPES OF MILLET

Millets are categorized into two types: major millets and minor millets. The major millets include Pearl millet, Proso or white millet, Foxtail millet, and Finger millet On the other hand, the minor millets comprise Barnyard millet, Little millet, Guinea millet, Kodo millet and Sorghum. The distinctive characteristics of millets are outlined in Table 3.

Table 1: Distinctive features of millet (Kalse et al., 2022)

Millet	Picture	Scientific name	Common name	Color	Shape and size	Origin
Finger millet		*Eleusine coracana*	Ragi, Wimbi, Kapai, Nagli, Marua, Mandua, Nachni	Colour - Light brown to dark brown. .	Shape – Spherical Size - 1–2 mm in dia	East Central Africa (Uganda)
Pearl millet		*Pennisetum glaucum*	Bajra, Cattail millet, Black millet, German millet	Colour- White, grey, pale yellow, brown, or purple.	Size 3–4 mm length Shape - Ovoid	Tropical West Africa (Sahel)

Proso millet		*Panicum miliaceum*	Cheena, Common millet, Broom millet, Vari	Colour - White cream, yellow, orange	Size - 3 mm long and 2 mm in dia Shape - Spherical to oval	Central and eastern Asia
Foxtail millet		*Setaria italic*	Indian paspalum, Kangni, Water couch, Italian millet, Rala	Colour - Pale yellow to orange	Shape - Ovoid Size -2mm length	China
Kodo millet		*Paspalum scrobiculatum*	Kodara, Ditch millet, Creeping paspalum	Colour- Blackish brown to dark brown	Size - 1.2 to 9.5 µm long Shape - Elliptical to oval	India & West Africa
Barnyard millet		*Echinochloa crusgalli*	Bhagar, Sawan, Jhingora, Kudraivali, Oodalu, Barti	Colour – White	Size – 2-3 mm long Shape – Tiny round	Japan & India
Little millet		*Panicum sumatrense*	Kutki, Samai, Samalu, Haliv	Colour - Grey to straw white	Size - 1.8 to 1.9 mm long Shape - Elliptical to Oval	Southeast Asia

II. PRODUCTION STATUS

Millets are among the major cereal grains consumed globally, particularly in arid and semi-arid regions of Africa and Asia, notably India and China. They are valued for their high nutritional content and agro-industrial significance (Saleh et al., 2013).

World millet production

Millet ranks as the sixth-highest yielding grain worldwide. The global millet production was estimated at 31,019,370 tonnes, with India being the largest producer, followed by Niger, China and other countries (FAO, 2020). The millet production will total 30.802 million Metric Ton in 2023/2024, which corresponds to a decline of 4.1% compared to the previous year (Mundus Agri, 2024).

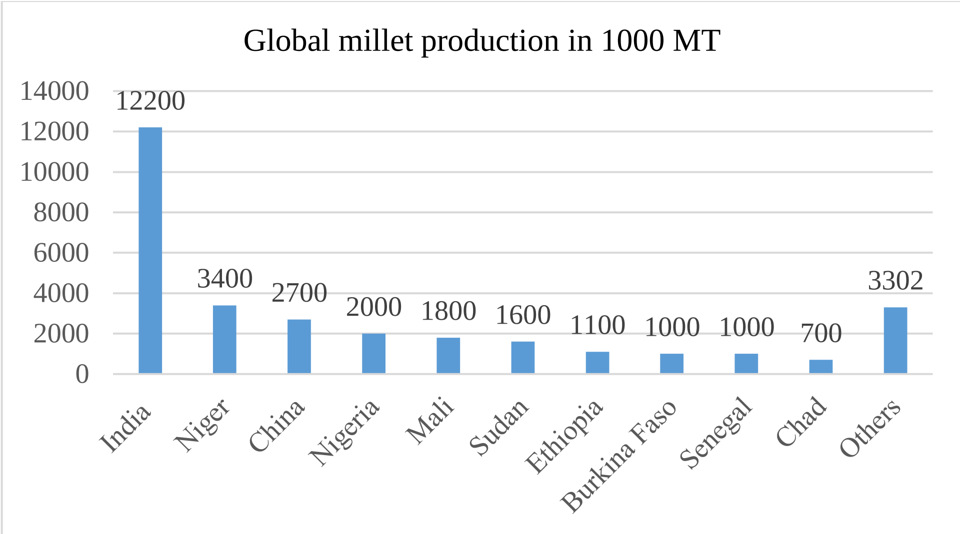

Fig.1: World production of millet (million tonnes), (Mundus Agri, 2024)

Millet production has shown stability in recent years, with an estimated output of 28 million metric tons in 2023. The majority of millet is cultivated in Africa, followed by Asia, with India leading as the largest producer, followed by Niger and China. Other significant millet-producing countries include Burkina Faso, Mali, and Senegal. Although millet is not a major food crop in developed nations, it holds significant importance in the diets of many people in developing countries (APEDA, 2023).

Indian millet production

In recent years, millet production in India has been increasing steadily. India is among the largest producers of millets globally, and Indian farmers are increasingly cultivating millets due to their drought-resistant nature. The Indian government has actively promoted millet production through initiatives like the National Food Security Mission. Consequently, millet production in India is projected to continue expanding in the future. The total production of Millets in the country during 2022-23 is 17.32 million tonnes (APEDA, 2023).

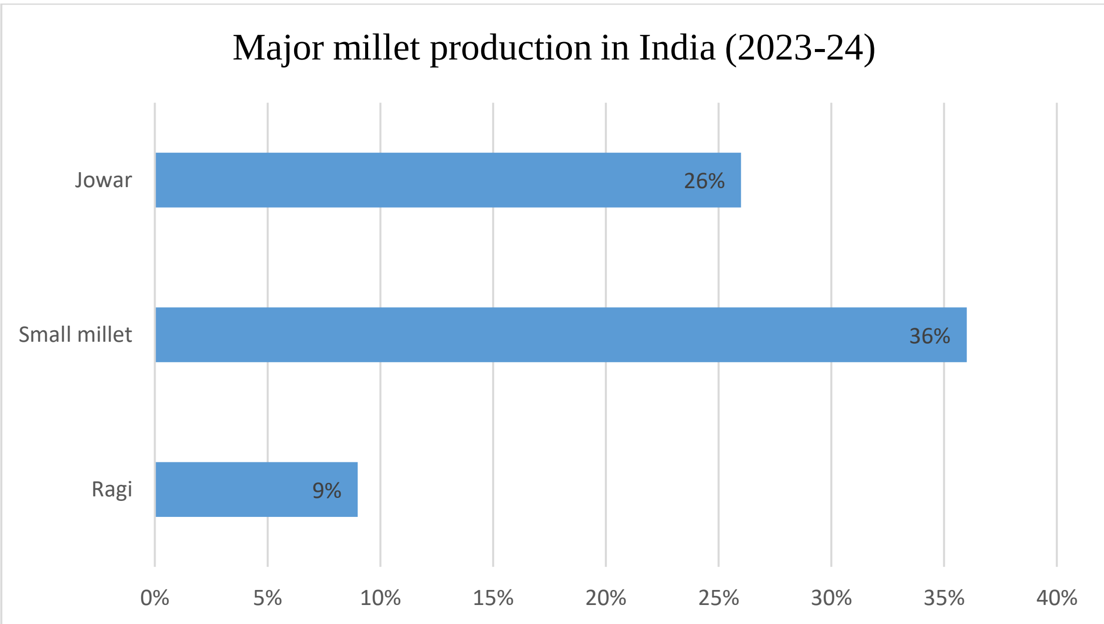

Fig.2: Millet production in India (APEDA, 2023)

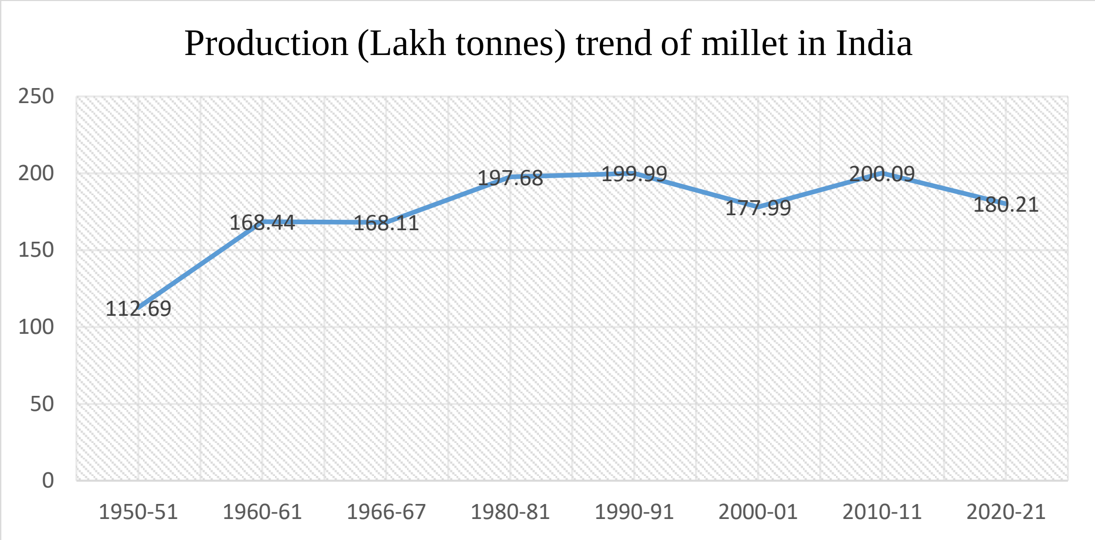

Fig.3: The production trends of millets in India (APEDA, 2022)

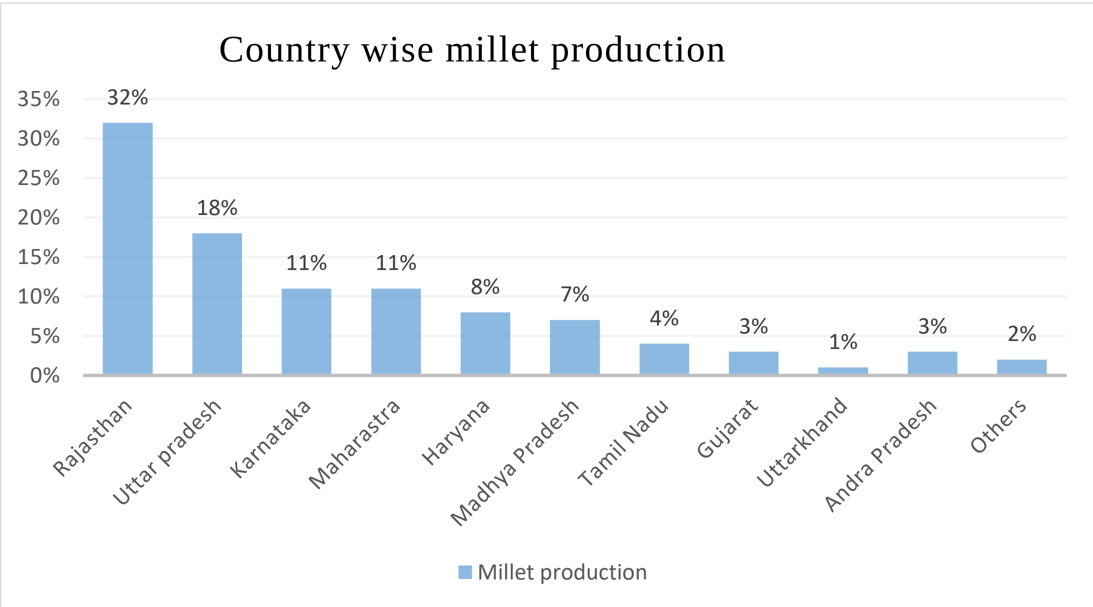

Fig.4: State wise production of millet (APEDA, 2023)

III. PHYSICAL CHARACTERISTICS OF MILLET

The kernel characteristics of various millets exhibit significant diversity. Millets can be categorized into two types based on their seed structure: utricles and caryopses. Utricle-type millets, such as finger millet, proso millet, and foxtail millet, have a pericarp that surrounds the seed like a sac but is attached to the seed at only one point. In these millets, the pericarp typically separates from the seed coat (testa), which is well-developed, thick, and forms a strong barrier around the endosperm. On the other hand, caryopsis-type millets, including pearl millet, fonio, and teff, have a pericarp that is completely fused to the seed. The endosperm accounts for the majority of the kernel weight across all millets. It comprises four structural parts: the aleurone layer, peripheral endosperm, corneous endosperm, and floury endosperm. All millets have a single-layer aleurone that surrounds the endosperm. The aleurone cells are rectangular with thick cell walls and contain protein, oil, minerals, and enzymes. The peripheral, corneous, and floury endosperm areas are located beneath the aleurone layer in that sequence (McDonough, 2000).

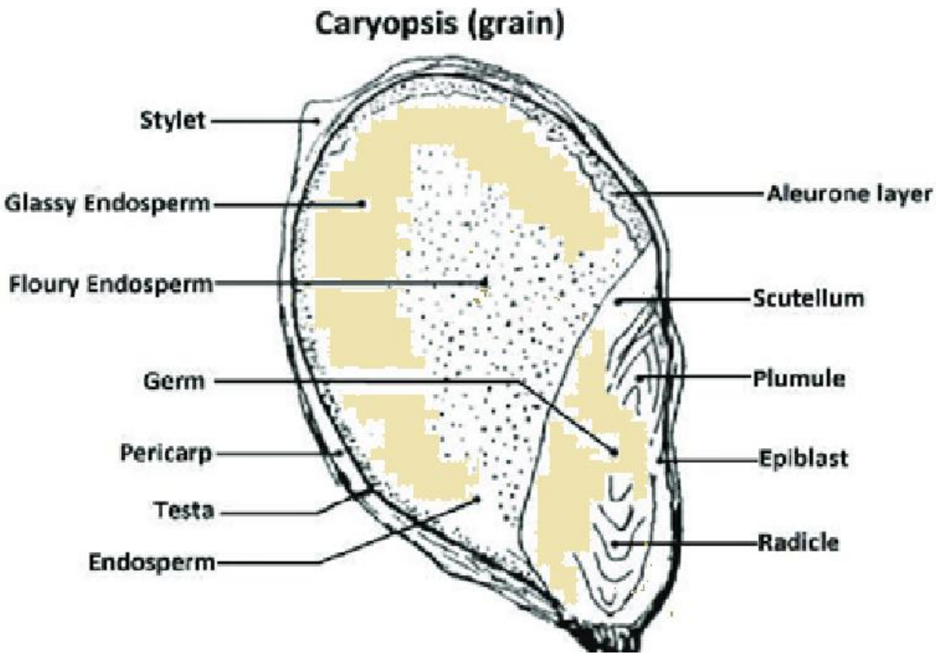

Fig.5: Structure of millet (Dayakar et al., 2016)

IV. NUTRITIONAL QUALITY OF MILLETS

The nutritional quality of food plays a critical role in maintaining overall human physical well-being, as it contributes to sustained health and development while maximizing human genetic potential. Therefore, addressing deep-rooted food insecurity and malnutrition requires a focus on dietary quality (Singh & Raghuvanshi, 2012). Whole-foods and plant-based diets have been shown to offer numerous health benefits and are associated with reduced risk of various diseases, including cancer, diabetes, obesity, and heart diseases (Chandrasekara & Shahidi, 2012).

Millets are rich in physiologically active substances and offer numerous health benefits, including a high antioxidant content, significant fiber content, low glycemic index, and gluten-free protein. Millets serve as an excellent source of energy, protein, and minerals due to their nutritional composition. They contain essential vitamins such as niacin (B3), thiamine, riboflavin, and folic acid. Approximately 70% of millet grains consist of carbohydrates, predominantly soluble carbohydrates and dietary fiber. The majority of millet polysaccharides comprise amylopectin and amylose (70–80%). Additionally, millets are abundant in polyphenols (0.2–0.5%), tannins, and phytates, which contribute significantly to their antioxidant activity and play a role in regulating the aging process. Finger millet, in particular, stands out with the highest calcium content among grains, at 344 mg/100 g (Tripathi *et al.*, 2023).

Millets and their food products are known to contain biologically active compounds with antioxidant potential (Izadi *et al.*, 2012). Millet-based products such as millet porridge, millet wine, and millet nutrition powder, both from whole grain and flour forms, are increasingly becoming part of people's daily lives (Subramanian *et al.*, 2007; Liu *et al.*, 2012). Resistant starch (RS) is a type of starch that resists enzymatic hydrolysis for at least 120 minutes after ingestion in the stomach and small intestine. RS is classified as a dietary fiber (DF) and offers similar health benefits to other non-starch polysaccharides (NSP) (Meenu & Xu, 2019; Shen et al., 2017; Nugent, 2005).It is considered a potential substitute for traditional dietary fibers such as inulin, β-glucan, and cellulose, mainly because of its minimal impact on sensory attributes and favorable cost economics (Charalampopoulos et al., 2002). The main source of starch comes from cereals. According to a FAO report, global cereal demand is projected to increase significantly, reaching 3036 million tons by 2028 (OECD/FAO, 2019).

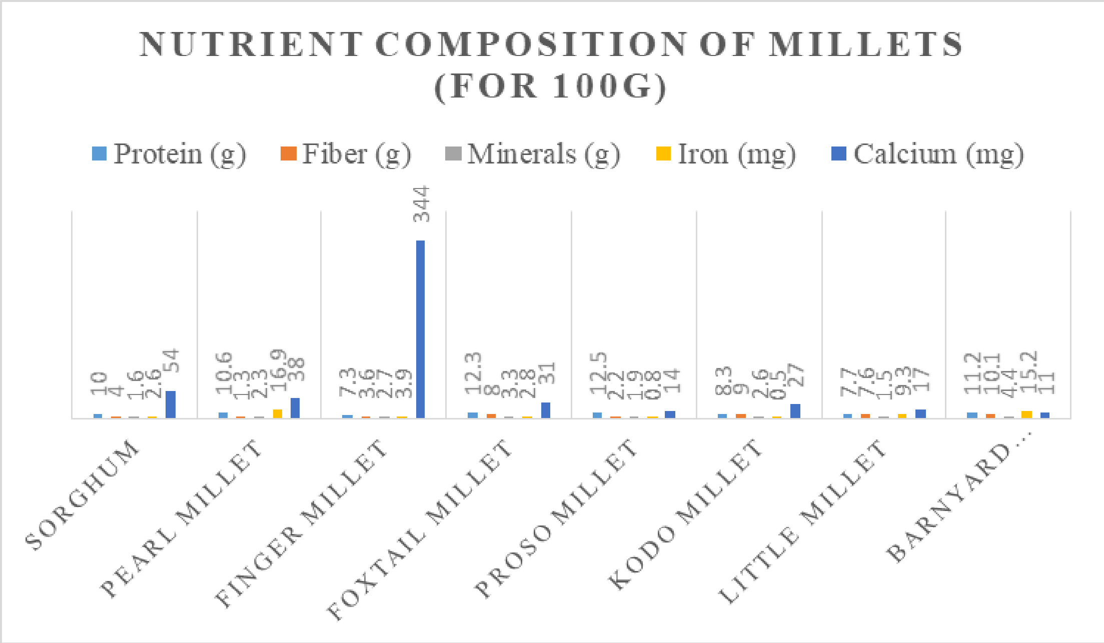

Fig.6: Nutritional composition of millets (for 100 g) (Indian Institute of Millet Research (IIMR))

FUNCTIONAL CHARACTERISTICS OF MILLET

Functional properties refer to the fundamental physicochemical and/or organoleptic properties of food components that provide health benefits to consumers (Chandra & Samsher, 2013; Siddiq et al., 2009). Ready-to-eat food is characterized by its texture, nutrient structure, nutritional value, and bioavailability of nutrients, among other factors, imparted by its various constituents. Parameters such as water absorption capacity, hydration (water binding), oil absorption capacity, swelling capacity, solubility, emulsifying activity, emulsion stability, foam capacity, foam stability, bulk density, gelatinization, dextrinization, denaturation, coagulation, gluten formation, aeration, elasticity, viscosity, jelling, and shortening (Chandra & Samsher, 2013) are essential considerations when selecting ingredients for functional foods. Additionally, the type, nature, structure, and configuration of components like carbohydrates, proteins, amino acids, fats and oils, and fiber must be analyzed.

Functional properties are essential physicochemical characteristics that describe how food components interact within specific environmental conditions. These properties help evaluate and predict how new proteins, fats, fibers, and carbohydrates will perform in different systems, assessing whether they can replace or complement traditional ingredients (Kaur *et al.*, 2006; Siddiq *et al.*, 2009). Food properties encompass the structure, quality, nutritional value, and consumer acceptability of a food product. Functional properties are defined by their physical, chemical, and sensory attributes (Abah *et al.*, 2020).

It is crucial to evaluate how processing conditions and parameters affect the behaviour of food constituents. For instance, the oil and water-binding capacities of food protein depend on factors such as conformation, amino acid composition, and surface polarity or hydrophobicity (Chandra & Samsher, 2013). In summary, before incorporating millet into a specific food product, it is important to thoroughly understand all of its essential physicochemical properties.

HEALTH BENEFITS ASSOCIATED WITH MILLETS

Diets rich in plant-based foods have demonstrated protective effects against various degenerative diseases, such as cancer, cardiovascular disease, diabetes, metabolic syndrome, and Parkinson's disease, based on epidemiological evidence (Chandrasekara *et al.*, 2012). The U.S. Department of Agriculture (USDA) has adjusted its nutritional guidelines to emphasize the importance of including grains or grain products in a regular diet for optimal health, placing them at the base of the food guide pyramid (USDA 2000; USDA 2005).

Table 2: Health benefits of millets

Millet type	Health benefits	Diseases	Positive side	Negative side	Refernces
Finger millet	Rich in calcium, iron and dietary fiber	Helps prevent anemia and osteoporosis	Gluten-free, high in antioxidants	May cause allergic reactions in some individuals	(Saleh et al., 2013)
Pearl millet	Good source of protein and B-complex vitamins	Aid in diabetes management	Drought-resistant, suitable for arid regions	Limited data on long-term effects	(Saleh et al., 2013; Gupta et al., 2018)
Foxtail millet	Low glycemic index, rich in antioxidants	Help in weight management	Easily digestible, gluten-free	May cause digestive issues for some individuals	(Saleh et al., 2013; Chandrasekara & Shahidi, 2010)
Proso millet	High in protein, low in	Support heart health and blood sugar control	Quick cooking time, versatile in recipes	Limited availability in some regions	(Saleh et al., 2013; Singh & Singh, 2015)
Barnyard Millet	Gluten-free, rich in fiber and essential amino acids	Assist in reducing cholesterol levels	Easily digestible, suitable for diverse diets	Limited studies on nutritional composition	(Saleh et al., 2013)
Little Millet	High in iron and essential minerals	Aid in managing blood pressure	Cultivates in various climates, sustainable crop	Limited awareness and market availability	(Saleh et al., 2013)
Kodo Millet	Contains antioxidants and essential fatty acids	Contribute to weight loss and diabetes control	Fast-growing crop, resistant to pests and diseases	May have a slightly bitter taste	(Saleh et al., 2013; Chandrasekara & Shahidi, 2010)

V. PROCESSING OF MILLETS

Various processing technologies are utilized to produce value-added food products while enhancing nutritional characteristics, sensory properties, and accessibility. The bioavailability of micronutrients in plant-based diets can be enhanced through traditional and mechanical food processing techniques, including germination/malting, soaking, fermentation, mechanical processing, and thermal processing. These methods aim to improve the physical accessibility of micronutrients, reduce antinutrient levels such as phytates, or increase the content of compounds that enhance bioavailability (Hotz & Gibson, 2007). The straightforward processing methods contribute to the continued use of these grains as staples in the diets of indigenous populations (Kalse *et al.*, 2022).

Table 3: The processing steps involved in millet processing

Processing Step	Description	Technical Details / Equipment Used
Cleaning	Removal of foreign materials, debris, and impurities	Winnowing, sieving, aspiration
Dehulling	Removal of outer hull or husk	Dehuller machine, abrasive rollers
Destoning	Removal of stones and heavier impurities	Destoner machine
Washing	Rinsing to remove dirt and residual impurities	Water rinsing or washing process

Drying	Reduction of moisture content to prevent spoilage	Sun drying, mechanical drying, hot air drying
Millin	Grinding millet grains into flour or meal	Hammer mill, stone mill, disc mill, attrition mill
Sievin	Separation of flour particles into different sizes	Vibrating sieve, mesh screen
Packagin	Packing processed millet products for storage and sale	Food-grade packaging materials

VI. MECHANISED PROCESSING TECHNOLOGY

1. Decortication/Dehulling

Decortication refers to the removal of the pericarp, hull, and outer coat of the grain. Millet grains like finger millet, pearl millet, and sorghum do not require decortication because they lack a husk covering (N. Sharma & Niranjan, 2018).

Small millets such as Foxtail, Little, Kodo, Proso, and Barnyard millet have a hard cellulosic husk layer that humans cannot digest, making husk removal a primary processing task (Tiwari *et al.*, 2023). The dehulling method and machinery used affect milling characteristics and nutrient retention. During large-scale processing, approximately 12 to 30 percent of the husk is removed along with almost all of the bran layer, leading to a decrease in nutritional value of millet products. Phenolic content, which is higher in the husk and seed coat, is lost during dehulling, resulting in reduced dietary fiber and beneficial chemicals (Goudar & Sathisha, 2016).

2. Milling/Grinding and Sieving

Grinding or milling of grains is commonly performed to separate the endosperm, bran, and germ, reduce particle size, and facilitate the production of refined flour. The chemical composition of millet can undergo significant changes during the milling process. Removal of the bran, which contains higher concentrations of phytic acid and polyphenols compared to whole millet grains, during milling reduces the levels of these substances and improves protein and starch digestibility in final processed products like chapatti, bread (Rathore, 2016). Sieving is a fundamental process in food processing and various industries, facilitating efficient particle size separation and refinement. It allows for precise control over particle size distribution, contributing to the quality and consistency of final products.

3. Fermentation

Fermentation is a natural process involving the conversion of sugars into alcohol or organic acids by yeast or bacteria and is one of the oldest and most economical methods of food preservation (Fujimoto *et al.*, 2019). Fermenting millet can enhance its nutritional value, safety, flavor, and texture. Common fermented millet products include millet beer, sourdough bread, and fermented porridge. It plays a vital role in modern food processing, offering efficient and controlled methods to harness the transformative power of microorganisms for food production and preservation.

4. Puffing

Puffing, a high-temperature short-time (HTST) processing method, is used to produce expanded cereals for snacks, breakfast, and ready-to-eat products, imparting desired flavor and aroma (Kapoor, 2013). This technique significantly alters the nutrient profile of grains and is commonly employed to create ready-to-eat snacks from various grains. To prepare popped millet, grains are pre-soaked to achieve the required moisture level, then exposed to hot sand at a ratio of 1:6 under high temperature (230-250 °C) for a short duration (20–30 s). Popping of decorticated finger millet is a common outcome when raw grains are rapidly heated to achieve expansion. Before heating, raw grains must be flattened and adjusted to the desired moisture content to achieve optimal expansion (Saleh *et al.*, 2013).

5. Malting

Malting involves the controlled germination of grains in a moist environment, activating enzymes like amylases and proteases that alter the grain's structure and composition (Awolu, 2017). This process enhances amino acids, total sugars, and B-complex vitamins while reducing starch and dry matter levels and increasing hydrolytic enzyme activity. The germination process activates enzymatic activity in sprouted seeds, leading to the breakdown of carbohydrates, proteins, and lipids into simpler forms (Singh *et al.*, 2015). Mechanized malting technology optimizes the malting process by providing controlled conditions that enhance enzyme activity, starch conversion and flavor development, ultimately producing high quality malt for brewing and other application.

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VII. CONVENTIONAL PROCESSING TECHNOLOGIES

1. Soaking:

Soaking grains is a common household food processing technique that greatly enhances the cooking of millet. By soaking millet in cold or hot water overnight, its nutritional value can be significantly improved. Soaking promotes the absorption of nutrients, including vitamins and minerals, and reduces cooking time. Moreover, soaking millet helps to break down antinutrients like phytic acid, which can impede mineral absorption in the gut. Soaking millet for 6-8 hours or overnight enhances its nutritional value, making it easier to digest and boosting its overall nutrient content (Bindra & Manju, 2019).

2.Cooking

Cooking is a common household method used to prepare traditional staple foods, and it can lead to changes in the nutrients of millet (Patel & Thorat, 2019). The nutritional content of millet may be affected by cooking, resulting in the loss of certain vitamins and minerals. The degree of nutrient loss depends on factors like cooking time, temperature, and the cooking method employed. Boiling millet in water, for instance, may cause some B-vitamins and minerals to leach into the cooking water, reducing the overall nutritional quality of the grain. To minimize nutrient loss, it is advisable to use cooking methods that retain as many nutrients as possible, such as steaming or pressure cooking.

3. Roasting

Roasting millet involves heating the grain in a dry pan until it achieves a golden-brown color and releases a nutty aroma. This process not only enhances the flavor and aroma of the grain but also aids in making it easier to digest. Roasting can also contribute to extending the shelf life of millet by eliminating moisture and deactivating potential contaminants. The temperature and duration of roasting can be adjusted based on personal preference and desired outcomes. Moreover, roasting can enhance the variety of aroma components, imparting a distinctive aroma to millets (Bi *et al.*, 2019; 2020).

VIII. ADVANCED PROCESSING TECHNOLOGY

1. Microwave technology

Microwave technology utilizes electromagnetic radiation within the frequency range of 300 MHz to 300 GHz. The application of microwave energy can lead to rapid moisture reduction in food items, though it may result in a decrease in nutritional content (Ekezie *et al.*, 2017; Gavahian *et al.*, 2019). Studies have shown that small millets treated with microwaves exhibit certain nutritional benefits, a trend also observed in foxtail millet flours (Dayakar Rao *et al.*, 2016; Kumar, Kaur *et al.*, 2020; Kumar, Sadiq *et al.*, 2020; Rao *et al.*, 2021). Microwaving can alter the structure of millet grains, thinning the stromal wall and creating a more uniform network (Zheng *et al.*, 2020). Microwave treatment offers a rapid, effective, and environmentally friendly method of food processing, although it may impact certain nutritional aspects (Almaiman *et al.*, 2021).

2. Infrared Technology

Infrared (IR) technology is a non-thermal preservation technique that has proven effective in reducing grain spoilage and extending the shelf life of millet. This method involves subjecting grains to IR treatment either in bulk or in a packed system under carefully monitored dosage settings. IR dosages have been shown to positively impact millets' antioxidant properties and shelf life (Wani *et al.*, 2021). In a storage study, IR methods were used to assess the stability of three types of millets (foxtail millet, sorghum, and pearl millet) over 90 days. The research found that at 0.50 kGy, fungal counts were not effectively reduced, but at 0.75 kGy or higher, γ-irradiation doses inhibited the proliferation of fungal microorganisms. This study indicates that IR treatment is a safe postharvest method for both whole and dehulled millets (H. Huang *et al.*, 2021).

3. Cold extrusion

Cold extrusion is a method used to process food using a single screw at temperatures below 100°C. The raw material is heated to a consistent temperature while being hydrated, mixed, and shaped (Shelar & Gaikwad, 2019). Popular cold-extruded products include pasta, vermicelli, noodles, flakes, and extruded rice, among others. Proso millet pasta, with an amylose content of approximately 20%, shows potential for gluten-free pasta production due to its gelling ability and high cold-paste consistency. Vermicelli made from barnyard millet exhibits significant levels of beta carotene (1039 μg/100g) and iron (3.81 mg/100g) (Goel *et al.*, 2021). Millet-based cold-extruded products generally exhibit a superior nutritional profile compared to conventional cold-extruded products (Sarojani *et al.*, 2021).

Table 4: Impact of processing technology on millet (Bajpai & Ravichandran, 2023)

Processing technology	Impact on millet
Milling	Increase in digestibility & bioavailability of nutrients especially protein & starch

	Decrease in dietary fiber, vitamins & minerals
Germination	Increase in digestibility & availability of protein & minerals Decrease the digestibility of macronutrients
Fermentation	Increase in the level of vitamins, minerals & amino acid Decrease the level of anti-nutrients like phytic acid
Puffing	Increase the protein concentration Decrease anti-nutritive component
Cooking	Increase the digestibility & nutritional value Decrease in vitamin & minerals
Boiling & Steaming	Maintain the nutritional value intact, especially in water-soluble vitamins. Decrease the absorption of minerals & reduce the level of antinutrients

IX. MILLET-BASED FOOD PRODUCTS

1. Baked products

The widespread popularity of bakery items worldwide has led to a significant increase in production due to their affordability, diverse tastes and textures, attractive packaging, and extended shelf life for convenient marketing (Patel et al., 1996; Silva et al., 2021). Millets offer superior fiber content and micronutrient profiles when incorporated into bakery products, presenting a strong opportunity for millets to penetrate the baking industry with various value-added products (Verma & Patel, 2013). Given the lower gluten content in most millets, they are typically added in varying proportions, such as 10% to 50%, to standardize products like bread (20%), cake (30%), cookies (50%), soup sticks (20%), and khari (40%), all typically made using refined wheat flour (Patel, 2013).

2. Extruded Products

Extrusion cooking is a high-temperature short-time (HTST) cooking method suitable for both proteinaceous and starchy materials. It offers several advantages including versatility, high throughput, product quality enhancement, and improved in-vitro protein digestibility (Adeleye *et al.*, 2020; Dahlin and Lorenz, 1993), while minimizing waste in food production. The process involves applying heat directly via steam injection, indirectly through the jacket, or by mechanical energy from shearing within the mixture (Onyango *et al.*, 2004). Proper equipment settings for feed rate, temperature, residence time, and pressure are crucial. By varying flour compositions, feed rates, cooking temperatures, pressures, and residence times, a wide range of millet-based extruded products with diverse attributes can be produced (Kalse *et al.*, 2022).

3. Fermented products

In various regions of India, fermented dishes like dosa and idli are popular breakfast and evening meal options. Millets are rich in protein, but their protein quality is a focus due to their low lysine and tryptophan content. Fermentation not only enhances flavor but also improves the nutritional profile of food by increasing protein, calcium, fiber and vitamins. Additionally, fermentation boosts in vitro protein digestibility and reduces antinutrient levels (Ali Maha *et al.*, 2003; Chavan *et al.*, 1989; Ikram Ali., *et al.*, 2021; Verma *et al.*, 2013).

4. Flour/Composite Flour

Using millet flour, either alone or in combination with other common flours, is a traditional practice for human consumption. Blending millet flour with other types of flour in specific proportions is essential to achieve the desired physicochemical, nutritional, and functional characteristics. Studies have shown that substituting wheat flour with grains like finger millet, proso millet, or barnyard millet at ratios of 20%, 10%, and 15% respectively is feasible. However, increasing the amount of millet flour in the mixture leads to higher ash content but decreases protein content, gluten value, dough loaf volume, and the percentage of damaged starch (Kaur & Singh, 2005).

5. Millet-based pasta and other products

Pasta and other millet-based products, such as papad, are made using dried goods and flour from grains or legumes as the main ingredient. Noodles, which are commonly known as convenience foods, are pasta items produced using cold extrusion technology and become hard and brittle after drying. Pasta can be extruded by using a dolly pasta machine. Noodles, valued for their longer shelf life and commercial appeal, are a popular food among people of all ages. Barnyard millet exhibits a slow digestion rate of 25.88% and a relatively low carbohydrate content of 58.56% (Abah *et al.*, 2020; Veena *et al.*, 2010).

6. Puffed/popped and flaked millet products

Puffing or popping is an ancient technique involving the heating of grains to create a snack or morning cereal, often seasoned with spices, salt, or sweeteners. During puffing or popping, millet grains or preconditioned pasta undergo structural transformations, expanding and resulting in a puffed product with desirable texture and

crispness. Engineering factors such as moisture content, porosity, bulk density, kernel size and ingredient composition (e.g., salt or sugar) influence popping volume and ratio (Sumathi *et al.*, 2007). Starch gelatinization levels are highest in roller-dried millet products, followed by popped, flaked and extruded varieties, each exhibiting distinct microstructural characteristics (Fujita *et al.*, 1996; Yanyu *et al.*, 2020).

Table 5: Millet-Based Products and Preparation Technologies

Millet based products	**Technology Used**	**Key Characteristics**	**Reference**
Millet Flour	Milling (stone or hammer mills)	Fine texture, versatile ingredient	Kumar et al., 2024
Millet Bread	Baking (conventional or artisanal)	Nutritious, gluten-free option	Shah et al., 2023
Millet Porridge	Boiling or steaming	Traditional breakfast dish	Shah et al., 2023
Millet Pasta	Extrusion	Pasta shapes, high protein	Palavecino et al., 2020
Millet Snack Bars	Extrusion and drying	Convenient, on-the-go snack	Bhattacharya, 2022
Millet Noodles	Cold extrusion	Long strands, quick cooking	Palavecino et al., 2020
Millet Cookies	Baking (conventional or artisanal)	Sweet treat, crunchy texture	Shah et al., 2023
Millet Crackers	Baking or frying	Crispy, savory snack	Shah et al., 2023

X. MACHINERIES USED FOR MILLET PROCESSING:

Millets, being low-value and small-seeded crops, are often improperly cleaned, graded, and dried before sale, resulting in low market prices and posing storage challenges. The broad acceptance and consumption of millet crops and their products are hindered by factors such as hard pericarp, dark color, presence of antinutrients, and limited availability of secondary processing equipment. Developing simple primary millet processing technologies could reduce drudgery associated with millet processing. Primary millet processing involves activities such as dehulling, destoning, cleaning, grading, milling, and sifting.

1. **Destoner for Millet:** This equipment effectively removes stones and contaminants from millet grains. It includes a 450 × 800 mm perforated dimple sheet deck for fluidization and separation, an aspirator with a centrifugal blower to remove lightweight impurities, and an oscillating sieve box made of wood (700 × 1000 mm) to hold two sieves with sieve-changing provisions (Kalse *et al.*, 2022).
2. **Millet Mill:** This device, powered by a single-phase electric motor, removes the outer husk from little millets using two adjustable abrasive rollers. Unhusked millets are fed through a hopper and fall between abrasive plates due to centrifugal force. Dehulled grains are collected through a bottom outlet, and a cyclone separator gathers dust and husk particles (Balasubramanian *et al.*, 2020).
3. **Grain Polisher:** Millets are dehusked and polished using a cone polisher, centrifugal rice sheller, or rice polisher. Barnyard millet can be polished using a rice polisher. The optimal degree of polishing is achieved with 10% (db) moisture content for 3 minutes of milling, though polishing reduces protein, fat, ash, and fiber concentrations (Lohani *et al.*, 2012).
4. **Grinder/Pulverizer:** Hammer mills, burr mills, or plate/disc mills are used to grind small millets. Minor millets typically undergo semi-wet or dry milling processes. Hammer mills are cost-effective for reducing decorticated grain particle size but can lead to flour caking and reduced process throughput due to overheating and moisture (Kalse *et al.*, 2022).
5. **Flour Shifter:** Grounded flour is sieved into two grades using a flour sifter equipped with stainless steel mesh (40-micron mesh size) and provisions for easy sieve removal and fastening. The outlet for fine and coarse materials is set at the proper height (Kalse *et al.*, 2022).

Table 6: The evolution of millet processing machinery over time

	Machinery Used for Millet Processing
	• Stone querns and mortars for grinding and dehulling millets • Hand-operated tools for winnowing and sorting millet grains • Traditional wooden pestles and mortars for grain pounding • Sieves made from woven materials for grain cleaning and sorting
	• Mechanical dehullers and grain cleaners for millet processing • Roller mills and abrasive decorticators for millet grain milling • Modern centrifugal separators for grain separation and cleaning
	• Automated millet processing lines with integrated sorting systems • Precision milling and sorting using advanced robotic technologies • Nanotechnology-enabled nutrient extraction and preservation

XI. CHALLENGES OF MILLET PROCESSING

Challenges associated with millet processing encompass various aspects that hinder efficient production and utilization of millets. One primary challenge is the lack of modern processing technologies tailored specifically for millets, which leads to inefficient and labour-intensive processing methods. Limited infrastructure and inadequate facilities for storage, transportation, and processing contribute to post-harvest losses and affect the quality of millet-based products. Millet processing faces several challenges, including expensive equipment, limited infrastructure in rural areas, inadequate supply chain logistics, and competition from subsidized grains like wheat and maize. Consistent quality control is challenging due to susceptibility to pests, moisture damage, and fungal contamination. Additionally, outdated technology may hinder large-scale production of high-quality millet products. Consumer familiarity, sensory characteristics, cost, and gestational cycle further contribute to processing limitations (Shah *et al.*, 2023).

XII. CONCLUSION

Technologies for value addition and post-harvest processing have advanced, allowing the creation of processed millet products that appeal to both urban and rural consumers. Millet processing has been integral to product development, showing positive trends in terms of quality and nutrition. Despite its recognized health benefits and potential as a cereal substitute, the full scope and applications of millets have yet to be fully explored. Further research employing advanced methods and diverse cooking techniques is necessary to evaluate the bioavailability of micronutrients such as minerals. The consumption of millets can contribute significantly to a balanced diet and help address global malnutrition challenges. Therefore, promoting millet consumption and improving processing technologies can play a crucial role in enhancing the overall health and nutrition of the population.

REFERENCES

[1] Abah C R., et al. "Sorghum grains: nutritional composition, functional properties and its food applications". European Journal of Nutrition and Food Safety 12.5 (2020): 101-111.

[2] Abah, C. R., Ishiwu, C. N., Obiegbuna, J. E., & Oladejo, A. A. (2020). Nutritional composition, functional properties and food applications of millet grains. *Asian Food Science Journal*, *14*(2), 9-19.

[3] Adeleye Oluwafunmilayo O., et al. "Effect of high-temperature,short-time cooking conditions on in vitro protein digestibility,enzyme inhibitor activity and amino acid profile of selectedlegume grains". Heliyon 6.11 (2020): e05419.

[4] Agricultural and processed food products export development authority (APEDA) https://apeda.gov.in/

[5] Almaiman, S.A., Albadr, N.A., Alsulaim, S., Alhuthayli, H.F., Osman, M.A. and Hassan, A.B. 2021. Effects of microwave heat treatment on fungal growth, functional properties, total phenolic content, and antioxidant activity of Maha sorghum (Sorghum bicolor L.) grain. Food Chemistry, 348: 128979.

[6] Awolu, O.O. 2017. Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. Heliyon, 3(2): e00240.

[7] Balasubramanian, S., Deshpande, S.D. and Bothe, I.R. 2020. Design, Development and Performance Evaluation of CIAE-Millet Mill. Agricultural Mechanization in Asia, Africa and Latin America, 51(1): 42–48.

[8] Bhandari, A. S., Jat, K. B., Kanse, A. A., Gorde, P. D., Suri, S., & Patil, A. G. (2023). Millets as Super Foods: A Review. *Acta Scientific NUTRITIONAL HEALTH (ISSN: 2582-1423)*, *7*(6).

[9] Bhattacharya, S. (2022). Snack Foods: Processing and Technology. Academic Press.

[10] BAJPAI, P., & Ravichandran, R. The Potential of Millet Grains: A Comprehensive Review of Nutritional Value, Processing Technologies, and Future Prospects for Food Security and Health Promotion. Journal of Cereal Research, 15(2).

[11] Bi, S., Wang, A., Wang, Y., Xu, X., Luo, D., Shen, Q. and Wu, J. 2019. Effect of cooking on aroma profiles of Chinese foxtail millet (*Setaria italica*) and correlation with sensory quality. *Food Chemistry*, 289: 680–692.

[12] Bi, S., Xu, X., Luo, D., Lao, F., Pang, X., Shen, Q., Hu, X. and Wu, J. 2020. Characterization of Key Aroma Compounds in Raw and Roasted Peas (*Pisum sativum* L.) by Application of Instrumental and Sensory Techniques. *Journal of Agricultural and Food Chemistry*, 68(9): 2718–2727.

[13] Bindra, D. and Manju. 2019. Whole grains and millets as raw ingredients for recipes in diabetes mellitus. *International Journal of Home Science*, 5(3): 214–219.

[14] Chandra, S., & Samsher. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*(38), 4849–4852

[15] Chandrasekara A, Naczk M, Shahidi F. Effect of processing on the antioxidant activity of millet grains. Food Chem. 2012;133:1–9.
[16] Chandrasekara, A., & Shahidi, F. (2010). Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. Journal of Agricultural and Food Chemistry, 58(11), 6706-6714.
[17] Chandrasekara, A., & Shahidi, F. (2012). Bioaccessibility and antioxidant potential of millet grain phenolics as affected by simulated in vitro digestion and microbial fermentation. Journal of Functional Foods, 4(1), 226–237. https://doi.org/10.1016/j. jff.2011.11.001
[18] Charalampopoulos, D., Wang, R., Pandiella, S., & Webb, C. (2002). Application of cereals and cereal components in functional foods: A review. *International Journal of Food Microbiology*, *79*(1–2), 131–141. https://doi.org/10.1016/S0168-1605(02)00187-3
[19] Chavan J K., et al. "Nutritional improvement of cereals by fermentation". Critical Reviews in Food Science and Nutrition 28.5 (1989): 349-400.
[20] Dahlin K and K Lorenz. "Protein digestibility of extruded cerealgrains". Food Chemistry 48.1 (1993): 13-18.
[21] Dai A (2011) Drought under global warming: a review. Wiley Interdiscip Rev Clim Change 2:45–65
[22] Dayakar Rao, B., Anis, M., Kalpana, K., Sunooj, K.V., Patil, J.V. and Ganesh, T. 2016. Influence of milling methods and particle size on hydration properties of sorghum flour and quality of sorghum biscuits. LWT - Food Science and Technology, 67: 8–13.
[23] Den Herder G, Van Isterdael G, Beeckman T, De Smet I (2010) The roots of a new green revolution. Trends Plant Sci 15:600–607
[24] Eduru, A., Kamboj, A., Reddy, P. M., & Pal, B. (2021). Nutritional and health benefits of millets, present status and future prospects: A review. The Pharma Innovation Journal, 10(5), 859-868.
[25] Ekezie, C.F.-G., Sun, D.-W., Han, Z. and Cheng, J.-H. 2017. Microwave-assisted food processing technologies for enhancing product quality and process efficiency: A review of recent developments. *Trends in Food Science & Technology*, 67: 58–69
[26] FAO. Annual Publication. Rome, Italy: Food and Agricultural Organization 2007. http://www.fao.org/3/a-a1200 e.pdf. Accessed 12 Dec 2019.
[27] FAO Cereal Supply and Demand Brief World Food Situation Food and Agriculture Organization of the United Nations. (n.d.). Retrieved March 26, 2020, from http:// www.fao.org/worldfoodsituation/csdb/en/.
[28] FAO. World Food and Agriculture—Statistical Yearbook; FAO: Rome, Italy, 2020.
[29] Fujimoto, A., Ito, K., Narushima, N. and Miyamoto, T. 2019. Identification of lactic acid bacteria and yeasts, and characterization of food components of sourdoughs used in Japanese bakeries. Journal of Bioscience and Bioengineering, 127(5): 575–581.
[30] Fujita S., et al. "Physicochemical studies of starch from millet (Setaria italica Beauv.)". Food Chemistry 55.3 (1996): 209-213.
[31] Gavahian, M., Chu, Y.-H. and Farahnaky, A. 2019. Effects of ohmic and microwave cooking on textural softening and physical properties of rice. *Journal of Food Engineering*, 243: 114–124.
[32] Goel, K., Goomer, S. and Aggarwal, D. 2021. Formulation and optimization of value-added barnyard millet vermicelli using response surface methodology. Asian Journal of Dairy and Food Research, 40(1): 55–61.
[33] Goron TL, Raizada MN (2015) Genetic diversity and genomic resources available for the small millet crops to accelerate a new green revolution. Front Plant Sci 6:157
[34] Goudar, G. and Sathisha, G.J. 2016. Effect of Processing on Ferulic Acid Content in Foxtail Millet (Setaria italica) Grain Cultivars Evaluated by HPTLC. Oriental Journal of Chemistry, 32(4): 2251–2258.
[35] Gupta, A. K., & Das, S. (2005). Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration. Current Science, 89(6), 944-951.
[36] Gupta, R. K., et al. (2018). Millets: A solution to agrarian and nutritional challenges. Agricultural Reviews, 37(1), 56-61.
[37] Harlan, J. R. (1992). Crops and Man. American Society of Agronomy. *Crop Science Society of America, Madison, Wisconsin*, *16*(2), 63-262.
[38] Hassan, Z. M., Sebola, N. A., & Mabelebele, M. (2021). The nutritional use of millet grain for food and feed: a review. *Agriculture & food security*, *10*, 1-14.
[39] Hotz, C. and Gibson, R.S. 2007. Traditional Food-Processing and Preparation Practices to Enhance the Bioavailability of Micronutrients in Plant-Based Diets. *The Journal of Nutrition*, 137(4): 1097–1100.
[40] Huang, H., Dikkala, P.K., Sridhar, K., Yang, H., Lee, J. and Tsai, F. 2021. Effect of heat and γ-irradiation on fungal load, pasting, and rheological characteristics of three whole and dehulled millets during storage. Journal of Food Processing and Preservation, 45(4).
[41] Ikram Ali., et al. "Nutritional and end-use perspectives of sprouted grains: A comprehensive review". Food Science and Nutrition 9.8 (2021): 4617-4628.
[42] Indian Institute of Millet Research (IIMR), https://www.millets.res.in/millets_info.php
[43] Izadi, Z., Nasirpour, A., Izadi, M., & Izadi, T. (2012). Reducing blood cholesterol by a healthy diet. International Food Research Journal, 19(1), 29–37.
[44] Jena, A., Sharma, V., & Dutta, U. (2023). Millets as superfoods: Let thy cereal be thy medicine. *Indian Journal of Gastroenterology*, *42*(3), 304-307.
[45] K., Singh, K., Singh, B., & Author, C. (2022). Millets processing, nutritional quality & fermented product: A review. The Pharma Innovation Journal, 11(5), 304-308.
[46] Kaimal, A. M., Mujumdar, A. S., & Thorat, B. N. (2021). Resistant starch from millets: Recent developments and applications in food industries. *Trends in Food Science & Technology*, *111*, 563-580.
[47] Kalse, S. B., Swami, S. B., & Jain, S. K. (2022). Millet: A Review of its Nutritional Content, Processing and Machineries. *International Journal of Food and Fermentation Technology*, *12*(1), 47-70.

[48] Kapoor, P. 2013. Nutritional and functional properties of popped little millet (Panicum sumatrense). McGill University.

[49] Kaur M, Singh N. Relationships between selected properties of seeds, flours, and starches from different chickpea cultivars. International Journal of Food Properties. 2006;9:597-608.

[50] Kaur, M. and Singh, N. 2005. Studies on functional, thermal and pasting properties of flours from different chickpea (Cicer arietinum L.) cultivars. Food Chemistry, 91(3): 403–411.

[51] Kaushik, N., Yadav, P., Khandal, R. K., & Aggarwal, M. (2021). Review of ways to enhance the nutritional properties of millets for their value-addition. *Journal of Food Processing and Preservation*, *45*(6), e15550.

[52] Kole C, Muthamilarasan M, Henry R, Edwards D, Sharma R, Abberton M et al (2015) Application of genomics-assisted breeding for generation of climate resilient crops: progress and prospects. Front Plant Sci 6:563. https ://doi.org/10.3389/fpls.2015.00563

[53] Kumar, A., Tomer, V., Kumar, M., & Chawla, P. (2024). Millets: Cultivation, Processing, and Utilization. CRC Press.

[54] Kumar, K. A., & Ganesamurthy, K. (2015). Millets–ancient grains for the future. International Journal of Science and Nature, 6(1), 18-23.

[55] Kumar, Kaur, C., Sethi, S. and Kaur Jambh, H. 2020. Effect of extruded finger millet on dough rheology and functional quality of pearl millet-based unleavened flatbread. Cereal Chemistry, 97(5): 991–998.

[56] Kumar, S.R., Sadiq, M.B. and Anal, A.K. 2020. Comparative study of physicochemical and functional properties of pan and microwave cooked underutilized millets (proso and little). LWT, 128: 109465.

[57] Liu J, Tang X, Zhang Y, Zhao W. Determination of the volatile composition in brown millet, milled millet and millet bran by gas chromatography/ mass spectrometry. Molecules. 2012;17:2271–82.

[58] Lohani, U.C., Pandey, J.P. and Shahi, N.C. 2012. Effect of Degree of Polishing on Milling Characteristics and Proximate Compositions of Barnyard Millet (Echinochloa frumentacea). Food and Bioprocess Technology, 5(3): 1113–1119.

[59] Majid, A., & Priyadarshini CG, P. (2020). Millet derived bioactive peptides: A review on their functional properties and health benefits. *Critical reviews in food science and nutrition*, *60*(19), 3342-3351.

[60] McDonough CM, Rooney LW, Serna-Saldivar SO. In: Kurl K, Ponte JG Jr, editors. The millets in handbook of cereal science and technology, second edition, revised and expanded, chap 4. New York: Marcel Dekker Inc; 2000.

[61] Meenu, M., & Xu, B. (2019). A critical review on anti-diabetic and anti-obesity effects of dietary resistant starch. Critical Reviews in Food Science and Nutrition, 59(18), 3019–3031. https://doi.org/10.1080/10408398.2018.1481360

[62] Mundus Agri: https://www.mundus-agri.eu/news/millet-global-production-decline-4-20232024.n32345.html

[63] Nithiyanantham, S., Kalaiselvi, P., Mahomoodally, M. F., Zengin, G., Abirami, A., & Srinivasan, G. (2019). Nutritional and functional roles of millets—A review. *Journal of food biochemistry*, *43*(7), e12859.

[64] Nugent, A. P. (2005). Health properties of resistant starch. Nutrition Bulletin, 30(1), 27–54. https://doi.org/10.1111/j.1467-3010.2005.00481.x

[65] OECD/FAO. (2019). OECD-FAO agricultural outlook 2019-2028. OECD (Organisation for Economic Co-operation and Development) . https://doi.org/ 10.1787/agr_outlook-2019-en

[66] Onyango Calvin., et al. “Proximate composition and digestibilityof fermented and extruded uji from maize–finger milletblend”. LWT-Food science and Technology 37.8 (2004): 827-832.

[67] Palavecino, P. M., Curti, M. I., Bustos, M. C., Penci, M. C., & Ribotta, P. D. (2020). Sorghum pasta and noodles: Technological and nutritional aspects. Plant foods for human nutrition, 75(3), 326-336.

[68] Patel. 2013. Value added products from nutri-cereals: Finger millet (Eleusine coracana). Emirates Journal of Food and Agriculture, 25(3): 169.

[69] Patel M M and G Venkateswara Rao. “Influence of untreated,heat-treated and germinated blackgram flours on biscuit makingquality of wheat flour”. Journal of Food Science and Technology33.1 (1996): 53-56.

[70] Patel, P. and Thorat, S.S. 2019. Studies on chemical, textural and color characteristics of decorticated finger millet (Eleusine coracana) fortified sponge cake. The Pharma Innovation Journal, 8(3): 64–67.

[71] Qi Yanyu., et al. “Insights into structure-function relationships of starch from foxtail millet cultivars grown in China”. International Journal of Biological Macromolecules 155 (2020): 1176- 1183.

[72] Rao, M.V., KG, A., CK, S., N, V. and R,J. 2021. Effect of microwave treatment on physical and functional properties of foxtail millet flour. International Journal of Chemical Studies, 9(1): 2762–2767.

[73] Rathore, S. 2016. Millet Grain Processing, Utilization and Its Role in Health Promotion: A Review. *International Journal of Nutrition and Food Sciences*, 5(5): 318.

[74] Saleh, A. S. M., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety*, *12*(3), 281–295. https://doi.org/10.1111/1541-4337.12012

[75] Sarojani, J.K., Suvarna, C.H., Hilli, J.S. and Sneha, S. 2021. Development of Ready to cook Kodo millet pasta. The Pharma Innovation Journal, 10(6): 910–915.

[76] Siddiq, M., Nasir, M., Ravi, R., Dolan, K. D., & Butt, M. S. (2009). Effect of defatted maize germ addition on the functional and textural properties of wheat flour. *International Journal of Food Properties*, *12*, 860–870. https://doi.org/10.1080/10942 91080 2103028

[77] Silva Daisy Jacqueline Sousa., et al. “Correlation between therheological and technological properties of biscuits with differentlevels of replacement of wheat flour by rice and azukibean flour”. International Journal of Food Science and Technology56.10 (2021): 5190-5200.

[78] Sood, P., Singh, R. K., & Prasad, M. (2019). Millets genetic engineering: the progress made and prospects for the future. *Plant Cell, Tissue and Organ Culture (PCTOC)*, *137*, 421-439
[79] Shah, M. A., Sunooj, K. V., & Mir, S. A. (Eds.). (2023). Cereal-Based Food Products. Springer Nature.
[80] Shah, P., Dhir, A., Joshi, R. and Tripathy, N. 2023. Opportunities and challenges in food entrepreneurship: In-depth qualitative investigation of millet entrepreneurs. Journal of Business Research, 155: 113372.
[81] Sharma, N. and Niranjan, K. 2018. Foxtail millet: Properties, processing, health benefits, and uses. *Food Reviews International*, 34(4): 329–363.
[82] Shelar, G.A. and Gaikwad, S.T. 2019. Extrusion in food processing: An overview. The Pharma Innovation Journal, 8(2): 564–568.
[83] Shen, D., Bai, H., Li, Z., Yu, Y., Zhang, H., & Chen, L. (2017). Positive effects of resistant starch supplementation on bowel function in healthy adults: A systematic review and meta-analysis of randomized controlled trials. *International Journal of Food Sciences & Nutrition*, *68*(2), 149–157. https://doi.org/10.1080/09637486.2016.1226275
[84] Singh AK, Rehal J, Kaur A, Jyot G. Enhancement of attributes of cereals by germination and fermentation: a review, Critical Reviews in Food Science and Nutrition. 2015;55(11):1575-1589.
[85] Singh P, Raghuvanshi RS. Finger millet for food and nutritional security. African Journal of Food Science. 2012;6(4):77–84.
[86] Sruthi, N. U., & Rao, P. S. (2021). Effect of processing on storage stability of millet flour: A review. *Trends in Food Science & Technology*, *112*, 58-74.
[87] Subramanian S, Viswanathan R. Bulk density and friction coefficients of selected minor millet grains and flours. Journal of Food Engineering. 2007;81(1):118–26.
[88] Sumathi A., et al. "Physico-chemical characteristics, nutritional quality and shelf-life of pearl millet based extrusion cooked supplementary foods". International Journal of Food Sciences and Nutrition 58.5 (2007): 350-362.
[89] Tiwari, H., Naresh, R. K., Bhatt, R., Kumar, Y., Das, D., & Kataria, S. K. (2023). Underutilized nutrient rich millets: challenges and solutions for India's food and nutritional security: a review. *International Journal of Plant & Soil Science*, *35*(2), 45-56.
[90] Tripathi, M.K.; Mohapatra, D.; Jadam, R.S.; Pandey, S.; Singh, V.; Kumar, V.; Kumar, A. Nutritional Composition of Millets. In Millets and Millet Technology; Springer: Berlin/Heidelberg, Germany, 2021; pp. 101–119.
[91] USDA. Dietary guidelines for Americans. US Government Printing Office. US Department of Agriculture, Department of Health and Human Services. Washington, DC; 2000.
[92] USDA. Nutrition and your health: dietary guidelines for Americans. US Department of Agriculture. Department of Health and Human Services, Washington, DC; 2005.
[93] Veena B., et al. "Development of barnyard millet based traditional foods". Karnataka Journal of Agricultural Sciences 17.3 (2010).
[94] Verma Veenu and S Patel. "Value added products from nutricereals:Finger millet (Eleusine coracana)". Emirates Journal ofFood and Agriculture (2013): 169-176.
[95] Wani, H.M., Sharma, P., Wani, I.A., Kothari, S.L. and Wani, A.A. 2021. Influence of γ-irradiation on antioxidant, thermal and rheological properties of native and irradiated whole grain millet flours. *International Journal of Food Science & Technology*, 56(8): 3752–3762.
[96] Yousaf, L., Hou, D., Liaqat, H., & Shen, Q. (2021). Millet: A review of its nutritional and functional changes during processing. *Food Research International*, *142*, 110197.
[97] Zheng, M., Xiao, Y., Yang, S., Liu, H., Liu, M., Yaqoob, S., Xu, X. and Liu, J. 2020. Effects of heat–moisture, autoclaving, and microwave treatments on physicochemical properties of proso millet starch. Food Science & Nutrition, 8(2): 735–743.